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DRAINAGE IN THE SACRAMENTO VALLEY RICE FIELDS

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The main outlet drain of Reclamation District 2047.

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INTRODUCTION

The necessity for adequate drainage in the rice growing areas of California is quite fully appreciated by all who are associated with the industry and considerable attention has been given to the drainage of these lands in the Sacramento Valley, with the result that several drainage and reclamation districts have been organized and many miles of drains constructed. Several of these have been in operation for sufficient time to justify some conclusions as to their efficiency in providing the required relief and the making of some suggestions regarding future work. In any general paper on drainage of rice lands a more comprehensive understanding of the situation can be obtained by the presentation of data on some of the interrelations between soils, irrigation, cultural methods and social and financial economies.

Location of Rice Areas.—The normal planting of rice in California³ is probably about 130,000 acres, although there is occasionally considerable variation from this figure. In 1924, there were slightly less than 90,000 acres, while in 1927 there were 169,000 acres of rice planted in California. These two years which mark the extremes since rice became really established, show a distribution by counties approximately as indicated in table 1.

In 1920 there were 162,000 acres of rice in the state and this was entirely in the Sacramento Valley. Although the rice planting in the state for 1927 exceeded by about 7,000 acres that of 1920, there was a decrease of nearly 13,000 acres in the Sacramento Valley. Due to the high prices which occurred in 1919 and 1920, there was a tendency to plant rice on types of soil which are not now considered as good rice soils.

¹ Responsibility for the drainage investigations reported in this bulletin lies with the Division of Soil Technology, but the studies were inaugurated by the Rice committee. This committee, which was appointed by the Director of the Experiment Station in 1921, is composed of Frank Adams, Chairman, P. L. Hibbard, J. W. Jones, P. B. Kennedy, W. W. Mackie, Chas. F. Shaw, E. J. Stirniman and W. W. Weir.

² Associate Drainage Engineer in the Experiment Station.

³ Although this paper deals particularly with the rice industry in the Sacramento Valley, other rice areas in the state will be briefly referred to at various times.

At the present time rice is grown extensively in five general areas in the Sacramento Valley and one in the San Joaquin Valley. In the Sacramento Valley these areas are referred to as (1) West Yolo County, between Woodland, Madison and Winters; (2) Lower Sutter and Colusa Basins, particularly in Reclamation Districts 1500 and 108; (3) West Side or Upper Colusa Basin between Williams and Willows; (4) East Side or that portion of Butte

TABLE 1
CALIFORNIA RICE ACREAGES BY COUNTIES FOR THE YEARS 1924 AND 1927.

County	1924	1927
	<i>acres</i>	<i>acres</i>
Glenn.....	13,200	28,000
Butte.....	22,500	35,000
Sutter.....	14,700	25,000
Yolo.....	14,100	21,000
Colusa.....	22,500	32,000
Yuba.....	(Included with Sutter)	5,000
Sacramento.....	2,600	4,000
San Joaquin Valley (largely Merced County).....		15,000
Imperial.....		4,000

County in the vicinity of Richvale, and west of Gridley and Biggs; (5) The Morrison Slough, Snake River section of Sutter County. Most of the rice grown in the San Joaquin Valley is located in the Merced Irrigation District south of Merced and a few thousand acres south of Dos Palos in Fresno County. As yet, the plantings in Imperial Valley have been scattered and inextensive, but when better cultural methods and varieties adapted to this region are established, it may become more important as a rice producing area. Each area contains soils which differ from those of the other areas and which respond to drainage in different ways.

SOILS OF THE RICE LANDS

The water requirement of rice is unlike that of any other crop grown in California in that complete and continuous submergence of the ground is necessary during the growing season of from 110 to 150 days. This long submergence period followed very shortly after harvest by the winter rainy season makes the time during which the soil may become dry and aerated very short. Figure 1 is a view taken in a rice field showing the ground surface covered with water.

The amount of irrigation water required to maintain continuous submergence for rice is so large as to preclude the economical pro-

duction of this crop except on those soils which are heavy and relatively impervious. The heavy texture of the soil adds to the difficulty with which rice lands are drained.

The first commercial plantings of rice in California (about 1400 acres in 1912) were located on the Stockton clay adobe⁴, or "black



Fig. 1.—A Sacramento Valley rice field nearing maturity. The field must be unwatered sufficiently in advance of maturity so that the soil will be dry enough to support the harvesting machinery when the crop is ready to bind.

adobe," soils in the vicinity of Biggs, Butte County. This is a dark gray to black clay from 18 inches to 36 inches in depth underlain with a light yellowish to brownish calcareous hardpan. In places the hardpan is several feet in thickness. This soil is very sticky and waxy when wet, but breaks down into a crumbly mass when dry so that cultivation is not particularly difficult. There is a large area of Stockton clay adobe in Butte County extending from a point about four miles south of Durham to the Sutter Buttes. A narrow strip extends around the east side of the Buttes and south of Sutter City for about ten miles. This soil has a flat even topography, is easily prepared for rice, rather impervious to the downward movement of water and relatively free from alkali. These conditions combined with its location in a region of favorable climate make

⁴ Reconnaissance soil survey of the Sacramento Valley, California. Field operations Bureau of Soils, 1913.

it particularly adapted to rice culture. In fact, this soil appears to produce rice more profitably than any of the other crops which have been tried. Barley, wheat, corn and a limited amount of truck are about the only other crops grown.

Figure 2 is a rice field on Stockton clay adobe which has been unwatered and is ready for the binder.



Fig. 2.—A rice field ready for the binder. Under favorable weather and drainage conditions it usually requires about ten days after unwatering is begun for the soil to become dry enough to bear up the harvesting machinery.

In the lower Sutter and Colusa basins and in the upper Yolo Basin rice is confined largely to the Sacramento clay soil⁵, ⁶. This soil is a dark gray or black clay of smooth waxy structure when wet and comparatively friable when well drained and dry. Sacramento clay is typically six feet or more in depth. This soil occupies smooth, flat depressions which would be subject to periodic overflow were it not for the levee protection.

The areas of Sacramento clay lying north of the Conway ranch, southeast of Woodland, have been extensively planted to rice and the

⁵ Soil survey of the Woodland area, California. Field operations Bureau of Soils, 1911.

⁶ Soil survey of the Marysville area, California. Field operations Bureau of Soils, 1909.

yields have been good. Rice has not been successfully grown on similar soils in Yolo Basin south of the Conway ranch because of unfavorable climatic conditions. The soils of the Sacramento series which are in rice are the best drained of any rice lands in the valley. It is probable, however, that factors, other than any peculiar inherent need for drainage which the Sacramento clay soil may possess, are responsible for the good drainage which has been supplied.

In the Willows or Upper Colusa Basin the principal soils on which rice is grown belong to the Willows⁷ series and consist of the clay, clay adobe and clay loam types. The clay of this series is frequently referred to as "the goose lands."

Typically the soils of the Willows series are brown to reddish brown on the surface with subsoils somewhat lighter in color. The subsoil is usually compact and in the heavier types is rather impervious to the movement of water. The "goose lands" and to a lesser extent the clay adobe type is frequently impregnated with alkali and the natural drainage is poor.

Due to the inherent poor drainage and alkali content of the Willows clay which does not appear to be readily overcome by artificial drainage, there has, in recent years, been a decided tendency to confine rice culture to the clay adobe and clay loam types of this soil.

In the Madison or West Yolo district, the principal rice soil is Capay clay and clay adobe, although in recent years the industry is extending westward onto soils of the Esparto and Yolo series.

Capay clay and clay adobe consist of two to three feet of heavy dark gray clay underlain with a light brown compact heavy clay. This is usually underlain at depths of about six feet with soils of a lighter texture. The drainage of these soils is fairly rapid except in inclosed depressions and they are not seriously affected by alkali.

Although the four principal rice soils in the Sacramento Valley have been mentioned, there is in the aggregate a considerable acreage of this crop grown on other soils such as San Joaquin loam, Kirkwood and Columbia clay loams, Marcuse clay, Gridley loam, Esparto and Yolo clay loams and a number of others of minor extent.

In Merced County most of the rice is grown on the heavy members of the Madera⁸ and Fresno series lying a short distance south of the city of Merced. These soils are brown and grayish brown in color,

⁷ Soil survey of the Colusa area, California. Field operations Bureau of Soils, 1907.

⁸ Soil survey of the Merced area, California. Field operations Bureau of Soils, 1914.

compact and very sticky and difficult to work when wet. The natural drainage is poor and in many places alkali is found in dangerous quantities. The Madera soil, aside from being somewhat hummocky, has a tendency to puddle and water enters with difficulty. In western Fresno County, Panoche clay adobe is the soil most extensively used for rice.

Considered only from the standpoint of its inherent characteristics, the most satisfactory soil for rice culture has been found to be a heavy clay three feet or more in depth which is relatively impervious to water but which when provided with proper drainage facilities will drain rapidly and become firm enough on the surface to bear up harvesting machinery within the shortest time after unwatering. Clay soils having an adobe structure appear to meet these requirements somewhat better than most other clays.

Alkali salts, when occurring in considerable quantity, not only affect the growth of the rice plant but interfere seriously with the drainage, and soils so affected have not proven entirely satisfactory. Alkali causes these soils to dry out much slower after unwatering. This difficulty has been encountered on the "goose lands" of the Upper Colusa Basin, the Fresno clays of Merced County, and the Imperial Valley soils.

Light-textured soils have not been generally satisfactory for rice, partly, because of the excessive water losses by seepage and deep percolation and its accompanying damage to adjoining lands. This latter characteristic has been particularly noticeable on the San Joaquin loams or red hardpan soils where harvesting may be delayed several days because the land is too wet to enter with machinery. It is believed also that under similar conditions, cat-tails and possibly some other weeds, grow more rapidly and are more difficult to control on light textured soils than on heavy.

Tank experiments made at the Biggs Rice Field Experiment Station show that the deep percolation and seepage losses from a rice field on Stockton clay adobe soils in 1926 and 1927 were respectively only 19 per cent and 14 per cent of the total water applied during the season. These low losses are an expression of the relative imperviousness of this soil and no doubt this characteristic influences its drainage.

DRAINAGE AND RECLAMATION⁹

Rice had been extensively grown for only two or three years in the territory around Richvale when the need for better drainage became apparent. Harvest was delayed because of the slowness with which the fields could be unwatered; and because there were no drainage ditches, lower fields suffered from the unwatering of these above.

Although the common practice in drainage as indicated by existing works may or may not be the most efficient, it should at least give a basis for comparisons and be indicative of what at the present time is considered economical drainage. A description of the work that has been done in the Sacramento Valley will therefore follow.

*Drainage District 100*¹⁰.—Drainage District 100 of Butte County, comprising about 19,000 acres in the Richvale section was the first of the so-called rice land drainage or reclamation districts to be organized. This district was organized in 1915 and the construction of a drainage system was begun immediately. The drains consist of ditches 3 to 6 feet deep and from one-half to one mile apart. For the most part they parallel the roads. The main drain along the Biggs-Princeton road is 8 feet or more in depth and its outlet is a tributary of Butte Creek known as Dry Creek. Figure 3 shows a drain typical of those in Drainage District 100 and Reclamation District 833. At the present time there are practically no tile or other type of closed or covered drains used in the rice lands.

Although the water table in the Richvale section is still very near the surface, the drains have served well to remove the surface water at the time of unwatering the rice fields. Drainage District 100 now has constructed about 79 miles of drains. These drains were designed to carry a run-off of $\frac{1}{2}$ inch in depth of water from the district each 24 hours, or about 15 cubic feet per second per square mile.

The original cost of construction, including sufficient for the first year's maintenance, was \$230,000. This amount was raised by the sale of 6 per cent district bonds. District 100 has since paid

⁹ At the end of this report is a map of a portion of the Sacramento Valley showing the location of the various drainage and reclamation districts.

¹⁰ The statistical material relating to reclamation and drainage districts appearing in this paper are based on data gathered by the author and supplemented by data from two unpublished reports: Sacramento Valley, West Side Area—1924, and Sacramento Valley, East Central Area—1925, prepared by Charles H. West, et al., Division of Rural Institutions, University of California, in cooperation with the Federal Land Bank of Berkeley.



Fig. 3.—Drainage ditch in District 100 which is typical of those found in the Stockton clay adobe soils of this region. Note the depth of surface soil and the underlying hardpan exposed on the left bank. Open drains of this general type when kept clean and free from weeds have proven satisfactory for the drainage of rice lands.

about \$12,000 for its share of outlet privileges into Butte Creek and about \$14,000 to Reclamation District 833 for land purchased by the latter for rights of way through Butte Basin. These two charges have been paid by special assessment.

In this district, as in all others, there is a heavy summer growth of cat-tails and other aquatic weeds in the drains. This interferes seriously with the flow in them at unwatering time and at other times tends to hold the water table nearer the surface than would be the case if they were kept clean. It would require, however, more than one cleaning a year to keep the drains clear of weeds and this is not a regular practice in any of the rice districts.

Operation and maintenance for District 100 has been about \$1.25 per acre per year, or about \$2.70 for each \$100 valuation. Land in this district is assessed at an average of \$45.00 per acre. Maintenance to date has consisted largely of annually cleaning the drains of weed growth and repairing them where necessary. Although an occasional new drain has been installed, the system is substantially as it existed at the completion of the original construction.

The soil in this district is Stockton clay adobe and is generally considered one of the best rice soils. The territory around Richvale is more thickly settled and a greater proportion of the rice growers are actual residents of their farms than in any other rice growing area. In 1924, there were 151 separate owners of land in District 100 and three-fifths of these owned less than 100 acres.

Because of the larger number of resident farmers on small farms, this region enjoys the distinction of being the best cared for of any of the rice areas. The drains are maintained in better shape, the land is better prepared and more attention is paid to fertilization and crop rotation.

Drainage District 200.—Joining District 100 on the east is the smaller Drainage District 200, which contains about 5470 acres. This district was organized in 1920, primarily to assist in the unwatering of rice lands, although some work was done on the east levee of Cherokee Canal to prevent overflow. The Biggs Rice Field Station of the United States Bureau of Plant Industry in cooperation with the University of California Agricultural Experiment Station is located in this district on Stockton clay adobe soils. The Stockton clay adobe soils of this district are not so black as those in District 100 and have been designated as the "brown phase" in recent soil surveys.¹¹ There is, in addition, a considerable area of Rocklin loam included in this district, but since 1920 only a small portion of this has been planted to rice. This soil, although having many of the requirements of a rice soil does not dry out as well at harvest time as does the Stockton and has a greater tendency to become foul with cat-tails.

The drainage system in District 200 is similar to that in District 100, the drains averaging from 4 to 5 feet in depth. The main drain which is about 5½ feet deep passes through a portion of Reclamation District 833 where it enters Lateral A of that district as its outlet.

The drainage system cost about \$145,000, including \$8000 paid to Reclamation District 833 for its share of the right of way in Butte Basin. Six per cent bonds were issued by the district to meet the construction cost. The bonded debt in this district varies from \$35.50 to \$12.00 per acre and maintenance is about \$1.00 per acre per year. Maintenance has consisted of periodic removal of weeds from the drains.

Rice, which is the principal crop, together with barley and wheat, constitute the only crops grown. A large portion of the area is in pasture.

¹¹ Soil survey of Oroville area, California. Field operations Bureau of Soils, 1926 (In press).

In 1924 there were only 52 land owners in the district, three-fifths of whom owned less than 100 acres each. The largest tract under single ownership is 626 acres. In this district, as in District 100, a considerable number of the rice growers are resident owners and farm well prepared land with good equipment. The drains, however, have not been kept free from weeds and cat-tails and the drainage is consequently not as efficient as might be desired.

Reclamation District 833.—Reclamation District 833, which comprises about 38,000 acres between the Cherokee Canal, and the Sutter-Butte Canal south of Drainage District 200, was organized in 1911. For various reasons construction work was delayed in this district until 1920 during which time the development of the rice industry greatly aggravated the poor drainage conditions. As a result, when work was actually begun the drainage of rice lands became an important feature in determining the type of drainage which was constructed.

The soils of this area are Stockton clay adobe, including the brown phase, Landlow loam and clay loam and Honcut sandy loam. At present, nearly all of the rice grown in this district is on the Stockton clay adobe and to a minor extent upon the brown phase of this soil. In former years there were rather extensive plantings of rice on Landlow clay loam west of Gridley, but this crop has now been largely replaced with alfalfa and barley or wheat.

The drainage system in this district consists of open drains from 5 to 6 feet in depth reaching every farm (see figure 3). There are a total of from 150 to 170 miles of main drain and laterals in the district. The outlet is through the lower end of Cherokee Canal into Butte Basin, where it was found necessary to purchase 727 acres of lowland to be used as a regulatory basin in order to prevent damage to lands owned by the Colusa-Delta Farms Land Company and to acquire flowage rights across an additional area of about 700 acres owned by several hunting clubs. Although originally acquired by District 833 the regulatory basin is now owned jointly by all of the drainage and reclamation districts which use Butte Basin as an outlet for the drainage from rice fields.

Before any rice was grown in this region, there was a need for drainage in portions of the area being farmed around Gridley and Biggs and east of the Southern Pacific tracks. During the irrigation season water could be found in the basements of buildings in Gridley. The drainage which has been done has greatly relieved this condition. Aside from those drains provided by the district, individual farmers

have constructed a few shallow surface drains which now give very satisfactory relief for those lands which are in cultivated crops.

There is still some land in the lower or western end of District 833 which is not adequately drained. This area is very flat and considerable alkali is to be found in places. Except for a small area in rice, these lowlands are not farmed and there is some doubt as to the present economic feasibility of providing sufficient drainage to put this land into a more productive condition.

The cost of drainage construction in Reclamation District 833 was \$1,227,000. This amount, together with \$273,000 to provide for 20 years' maintenance, making a total of \$1,500,000 was paid for through a bond issue. The drainage assessments in this district vary from \$60 per acre for some of the more desirable rice lands in the center to about \$40 for higher lands in the eastern portion of the district. In 1924, according to the county assessor's records, the average assessed value of the lands in this district, including the towns of Gridley and Biggs, was about \$72 per acre.

In 1924, 13,505 acres or 35.5 per cent of the district was in rice; 11,385 acres or 30 per cent was not in crop; 10,805 acres or 28 per cent was in grain, and the remainder, 2,300 acres, about equally divided between fruit and alfalfa. Of the area not in crop, a portion was in fallow and more than 2,000 acres were devoted to duck club hunting reserves. It may be noted from the above figures that about one-half of the cultivated area is in rice and, although the drainage system was planned to take care of both irrigation in the summer and rainfall in the winter from lands both in general crops and in rice, the main purpose of the system at the present time is to facilitate the unwatering of rice lands.

It is not probable that there will be any material increase in the cultivated acreage in this district unless some unusual stimulus occurs, such as the high price of rice in 1919. The rice acreage may, however, fluctuate from year to year with slight variations in the anticipated market. These fluctuations will be reflected in the acreage planted to barley and wheat rather than in the utilization of land which has been idle. This condition is believed to apply quite generally to all of the rice sections of the Sacramento Valley. Although District 833 as a whole is somewhat populous, only a very few of the rice growers are resident on the rice lands, most of them living in the towns or on the more intensively cultivated orchard and alfalfa lands.

Reclamation District 832.—Reclamation District 832, which lies between the western extremity of District 833 and the Marysville Buttes, is inactive. So far as can be learned, no work has been done. Most of this area is low and so poorly drained that very little of it is farmed. The lowest parts are owned or leased by duck clubs who are more concerned with the retention of water for ponds than they are with the reclamation of agricultural lands.

Butte Creek Drainage District.—Butte Creek Drainage District includes all of the rice lands which use water from the Feather River, the drainage from which passes through Butte Basin and which are not already included in some other reclamation district. This area of 36,663 acres lies principally north and west of District 100. The district has constructed no drains within its boundaries, but has assisted the neighboring districts in the construction of the Moulton Cut and in the purchase of a regulatory basin in Butte Basin. In 1927 and for several immediately preceding seasons, the area producing rice in Butte Creek Drainage District was less than at the time it was organized. The soils in this district are largely Landlow clay adobe, Marvin silty clay loam and Stockton clay adobe. All of these were extensively planted to rice in 1920, but at the present time very little rice is grown except on the Stockton soils which lie in that portion of the district east of the main channel of Butte Creek.

Drainage District 2.—Butte County Drainage District 2, comprising 7,965 acres, was organized in 1920 for the purpose of cleaning out about four miles of Dry Creek and constructing a drain two miles long and 100 feet wide to connect Dry Creek with Butte Creek. This district for the most part is included within the boundaries of Butte Creek Drainage District and was consequently responsible for its proportion of the regulatory works previously referred to. The work done by District 2 cost \$36,663 and was paid for by two special assessments totalling \$4.63 per acre.

Butte Basin.—As has already been mentioned, all of the area between the Sacramento River and the Feather River lying north of Gridley, drains into Butte Basin and around the west side of the Marysville Buttes into Sutter By-pass. This area includes the extensive rice areas included in Reclamation Districts 833, Drainage Districts 100 and 200, and Butte Creek Drainage District. The large amount of water entering Butte Basin during the early fall as the result of unwatering the rice fields was causing considerable damage to the bean lands of the Colusa Delta Farms Company and in 1920 this company enjoined all rice growers and the Western Canal Com-

pany from permitting any water which is taken from the Feather River for irrigation from entering Butte Basin. This action resulted in the organization of Butte Creek Drainage District in 1920. This district includes 36,663 acres made up of rice lands in the general area just described which were not already organized into a drainage or reclamation district. Reclamation District 833, being the first of the several districts organized, took the initiative and came to an agreement with the Colusa Delta Farms Company whereby a retarding basin of 727 acres was purchased and rights of way secured over about 700 additional acres. The cost of this land and right of way was about \$145,000 and has been absorbed by the various districts in proportion to their acreage. There has also been constructed the so-called Moulton Cut connecting the Sacramento River with the lower end of Butte Basin and the Sutter By-pass. This cut permits water from the Sacramento River at flood time to pass over the Moulton weir and through this region. The construction of this channel does not, however, materially relieve the winter flood conditions as now the flood from both Butte Creek and from the Sacramento River, over Moulton Weir, unite and sometimes overtop the ditch banks and flood this entire region.

As a part of the stipulation on rights of way through Butte Basin, the several districts have agreed to maintain for the benefit of the several gun clubs, a water level at an elevation between 47.3 feet and 48.8 feet above sea level. The districts have been required to build and control regulatory gates for this purpose.

Moulton District.—Reclamation District 1004, frequently referred to as the Moulton District was organized primarily for irrigation. It consists of 23,326 acres lying west of Butte Basin. The land in this district is held in large tracts, the Moulton interests being the principal owners. The district is bonded for \$550,000 or about \$25 per acre, and the money was used in the purchase of an irrigation pumping plant on the Sacramento River and a distributing system. All of the bonds are held by the Moulton Water Company. In 1918 during the rice boom, there were about 10,000 acres of rice in this district, but since then, except in 1927 when there was considerable acreage, the area so planted has been greatly reduced. This district has constructed a few drains, but was not involved in the purchase of the regulatory basin in Butte Sink as were those districts deriving their water supply from Feather River.

Reclamation Districts 2054 and 2056.—Reclamation Districts 2054 and 2056, lie east of Reclamation District 832 and south of District

833. Although this area has for many years had very poor drainage and remained wet until late in the spring, nothing was done to improve conditions until the advent of rice culture. On account of the heavy soils, consisting mostly of Stockton clay adobe, they were farmed to grain only in years of most favorable weather conditions. Rice has at some time been grown over a considerable part of the area and rather extensive drainage has been provided.

The drainage from these districts is carried to the east of the Marysville Buttes through the improved channels of Snake River and Morrison Slough and finally into the Sutter By-pass by way of the Intercepting Drain and the Wadsworth Canal. Both the Intercepting Drain and the Wadsworth Canal were constructed by the Sacramento-San Joaquin Drainage District as a part of their flood control program. The drainage systems in both these districts consist of deep open ditches which follow the natural depressions. The drainage of the individual farm is still rather inadequate for barley and wheat or general farm crops although each farm is now provided with an outlet. During the interim between the introduction of rice into this area and the construction of the drains, seepage and waterlogging caused considerable damage to orchards and vineyards in this vicinity. This in part was caused by attempting to carry the additional water required for rice in canals which had not yet been enlarged for this purpose.

Reclamation District 2054 was organized in 1922 and contains 14,515 acres. The main drains and principal laterals in this district are somewhat deeper than those in the districts farther north. The laterals average 6 feet deep, while the main drain is about 9 feet deep. Figure 4 shows the type of lateral drain which has been provided in Districts 2054 and 2056. The main drain of this district follows the natural depression of Snake River and the principal lateral, that of Black River, thus permitting a rather deep drain without excessive excavation. The drains in this district form excellent outlets for the rice fields; in fact, they are deeper than would be necessary if rice were the only crop to be considered.

Construction work in this district cost \$330,718 and the district is bonded for \$239,033. The bonded debt now averages \$22.78 per acre with a maximum of \$39.40 and a minimum of \$3.90 per acre. Maintenance and operation have averaged only about 50 cents per acre per year. In this district there are 117 owners. Only 5.6 per cent of the area, or 798 acres, was in rice in 1924, while 46 per cent of the land was in grain and about 42 per cent uncropped.



Fig. 4.—Lateral drains similar to this one touch each farm in Reclamation Districts 2054 and 2056. They are slightly deeper than in some of the other districts, but because they have not always been kept free from weeds may not be any more efficient.

Reclamation District 2056 is similar in many respects to the one just described, which it joins on the east. It was organized in 1922 and contains 8,780 acres. Morrison Slough, which, in its improved condition is used as the main drain, is a tributary of Snake River. The two districts have a common outlet. In general the drainage is somewhat better than in District 2054; however, in the vicinity of Live Oak where there are several orchards the water table is still rather high. The district spent \$258,516 in drainage works and is

bonded for \$201,285. Some of the better grain lands carry a bonded indebtedness of \$50 per acre for drainage. There is considerably more land suitable for general crops and fruit in this district than in District 2054. There are more than 3000 acres in orchards and vineyard and a like amount in grain. In 1924 less than 4 per cent of the district was planted to rice, while 30 per cent was not in crop. In both Districts 2054 and 2056, rice is confined to Stockton clay adobe soils, although during the rice boom considerable areas of Gridley soils were planted. The area devoted to rice in these two districts at the present time is so small as compared to other crops that the drainage systems can hardly be considered as applying to rice lands, although the rice industry was the incentive for their construction.

Area South of Sutter City.—In the region south of Sutter City and between the east levee of the Sutter By-pass and Levee District 1, are several thousand acres which are not included in any large drainage or reclamation district. In 1927 there were about 11,000 acres of rice grown in Sutter County outside of Reclamation District 1500 and most of it was in this region.

The soils are all heavy and belong to the Stockton, Sacramento and Marcuse series. Prior to the introduction of rice and construction of the protecting levees and drains, this area was subject to periodic overflow by water coming from both sides of the Marysville Buttes. The construction of the East and West Intercepting Drain on the north now prevents overflow from Snake River and its tributaries and the Sutter By-pass cuts off the drainage from the west.

Drainage of the rice fields is now well provided for by deep open drains. These, however, are not always well maintained and at times are allowed to grow up with cat-tails and water grass.

This area is drained by ditches constructed by the Sacramento-San Joaquin District and charged against a special assessment district. The outlet for part of it is through the Wadsworth Ditch into Sutter By-pass, but most of the water is carried to the lower part of the area and there pumped over the levee into the by-pass. The pumping plant is located about opposite the Tisdale weir. There are practically no crops other than rice grown in this area and with adequate drainage the soils seem well adapted to this crop.

Reclamation District 1500.—Reclamation District 1500, usually known as the Sutter Basin, comprises between 60,000 and 70,000 acres, or all of the land between the Sacramento River and the Sutter By-

pass, south of the Tisdale By-pass. This district is provided with more complete drainage than any other area in the Sacramento Valley. Deep drains averaging about one-half mile apart cross the district in both directions; these empty into a main which carries the drainage water to a large pumping plant at the south end of the district where it is discharged into the by-pass. In 1927 there were more than 13,000 acres of rice in this district, but the average annual planting is between 6000 and 7000 acres. The rice soils in this area are the heavy members of the Sacramento and Marcuse series. Rice plantings in this area are carefully supervised by the Sutter Basin Company and every effort made to eliminate drainage troubles. Eighty per cent of the 1927 crop was grown on land owned by the Sutter Basin Company and nearly half of this was operated by the company itself. The land is carefully prepared and the drains kept in good condition. It has been the general policy of the Sutter Basin Company to permit no rice to be grown adjacent to permanent crops such as alfalfa or orchards, but some deviation from this was observed in 1927.

Although drainage is more fully provided for in the Sutter Basin district than elsewhere in the rice growing areas—with the possible exception of a portion of District 108—and more care is used in the preparation of the fields, so as to provide the quickest possible unwatering and harvest after the crop is ripe, it is doubtful if the crops are any better or the yields heavier than on the best cared for lands in Butte County. It should not be overlooked in this connection that the climatic conditions are somewhat different in the two areas. Water grass and cat-tails are problems in this section as elsewhere, and rice is grown only two years in succession on the same land. Although the figures are not available, it is believed that this district has spent more money on reclamation than any other district and possibly more than is justified on rice land. It should be recognized, however, that the acreage of rice in this district is small as compared with other crops and that the drainage is adequate for any crop suited to the soils and climate of the region. The fact that rice growing is restricted to certain areas of heavy soils and the plantings are closely supervised by the Sutter Basin Company, are indicative of the subordinate position this crop holds in the farming operations of this district.

It can not be assumed that rice culture has materially influenced either the type of drainage installed in this district or the degree to which they are maintained and operated. Data pertaining to the cost of construction or the maintenance of these drains should there-

fore have but little bearing on the subject of rice land drainage. The significant feature in this area being that although rice unquestionably responds to good drainage, it is not necessary to provide the same type of drainage that is required for most crops.

Reclamation District 108.—A few thousand acres of rice (more than 10,000 acres have been reported in some years) are grown in Reclamation District 108, which lies across the Sacramento River, to the west of District 1500. These rice fields are well drained by numerous deep open ditches. The River Garden Farms Company,



Fig. 5.—The adequacy of the drainage in Reclamation Districts 1500 and 108 is a reasonable assurance that the crop can be harvested as soon as it is ready, thus minimizing the danger from adverse weather conditions. This view is on the River Garden Farms Company's property in Reclamation District 108.

who are the largest rice growers, exercise great care in the preparation of the land to facilitate rapid unwatering and uniform drying at harvest time. Figure 5 illustrates a well drained rice field in which there have been no losses due to harvesting when the ground is too wet or to lodging, rain or bird damage which may accompany an unreasonable delay in harvest.

The drains in this district are about 4 feet deep and one-half mile apart and although the system is not so elaborate, nor so well maintained as that in District 1500, it has been adequate for the needs of rice culture. The farming operations as practiced by these two large companies are greatly facilitated by the adequacy of the drainage systems. All of the rice in District 108 is grown on Sacramento clay.

In 1927 rice was grown on several hundred acres lying immediately west of Reclamation District 108 on Sacramento clay soils. So far as is known no special provision other than use of the main outlet drain of Reclamation District 2047 was made for the drainage of these fields and the crop yields were not materially inferior to those on adjoining similar, but better drained, soils.

West Yolo Section.— In Yolo County, south and southeast of Madison, there are usually from 12,000 to 15,000 acres of rice grown.



Fig. 6.—In the West Yolo area roadside ditches are frequently used to carry away water from the rice fields during the period of unwatering; even so, the drainage problem has not become a serious one.

The rice soils of this region are largely the clay and clay adobe of the Capay series, although occasional areas of Esparto and Yolo clays or clay loams are used.

This is the only large rice area in the Sacramento Valley which is not in a drainage or reclamation district or otherwise provided with drainage, and only a very limited amount of work has been done by individual owners in cleaning out the natural drainage channels.

The drainage problem here has not been as acute as in other districts and but little serious trouble has arisen. When the fields are unwatered prior to harvest, the waste water is turned into the road ditches and eventually finds its way into the Yolo basin by way of Willow Slough (see figure 6).

Some controversy has arisen over the flooding of lands east of the Woodland-Davis highway and in Yolo Basin with water from these rice fields, but no definite steps have been taken to prevent it.

The practice of turning waste water into the road ditches is not a satisfactory method of disposal as nearly always some fields at a lower elevation are endangered by waste from above. Many of the roads are impassable during this period and ingress and egress to farms is hampered. When fully unwatered, however, the Capay soils dry out quickly and harvest can be accomplished without difficulty.

There appears to be a smaller proportion of the land, other than fallow, lying idle in this Yolo County area than in any other of the rice producing sections. Water grass and cat-tails are not as yet so abundant here as in most rice sections and alkali injury is not common. It should be recalled that there is seldom a surplus of irrigation water in this section and, as will be discussed later, the duty of water is higher than in other rice areas. This fact leads to better farming methods, which in turn may account for less trouble with aquatic weeds.

The West Yolo district is the only extensive rice area in the Sacramento Valley where this crop is grown outside of the basin lands and with the exception of a few hundred acres on the Conway property southeast of Woodland is the farthest south of any rice in the Sacramento Valley.

Conway Ranch.—The Conway Ranch or Reclamation District 2035 is located in the Yolo Basin east of Woodland. This district was organized primarily to provide levee protection against overflow from Sacramento River flood waters in the Yolo By-pass. There are annually several hundred acres of rice grown in this district on Sacramento clay soil. Drainage has been provided for some of the rice fields and consists of open ditches about $\frac{1}{2}$ mile apart and about 4 feet deep. This drainage, where provided, is quite satisfactory for rice, although not nearly so good as that found in Sutter Basin on similar soils. There is some alkali to be found in this area and where drainage is not provided considerable difficulty has been found in satisfactorily unwatering the fields prior to harvest as well as in the excessive growth of cat-tails and weeds.

Two or three smaller areas of rice, also on Sacramento clay soils, are to be found along both sides of the Yolo By-pass between the Conway District and Knights Landing. These are provided with only shallow surface drains and as a consequence some difficulty has been encountered.

Reclamation District 2047.—The largest rice area in the Sacramento Valley both from the standpoint of area planted and of area available lies in Glenn and Colusa counties between Williams and Willows. This region is embraced within Reclamation District 2047. The rice soils in this area belong mostly to the Willows series and consist of the clay, clay adobe and clay loam types.

The first rice grown in this region was on the Willows clay or "goose lands"; but because of its flat, basin-like topography making it very difficult to drain, and because of the high alkali content, it has now been largely abandoned for rice. The tendency during the past few years has been to plant on only the better drained lands and as a result considerable of the rice is now being planted in the vicinity of and west of the state highway instead of in the trough of the basin.

Recently, and especially in 1927, there has been a very large planting of rice east of the trough of the basin from Colusa north to Jacinto. Just north of Colusa a few fields were located between the highway and the river on soils of the Columbia series. Better drained, lighter-textured soils with less alkali in the region east of the trough and a similar condition along the main line of the Southern Pacific railroad has undoubtedly caused the increased plantings in these two sections rather than in the trough of the basin.

As has been mentioned, this area is included within Reclamation District 2047. The district was organized in 1920 and has a gross area of about 230,000 acres. Nearly all of the land in this district is included also in some one of six irrigation districts, the Glenn-Colusa Irrigation District being the largest with 116,599 acres.

The drainage system as provided by Reclamation District 2047 consists of a main drain 75 miles long and about 155 miles of laterals. The main which follows the trough of the basin through the district extends southward through the lower Colusa Basin using the borrow pit of the west levee of Reclamation Districts 108 and 787. This drain has a capacity of about 1,500 cubic feet per second at its outlet, this being sufficient to take care of a run-off of about $\frac{1}{4}$ inch in 24 hours from the area included in the district. The outlet is just north of Knights Landing where the water is discharged into the Sacramento River by gravity at low river stages and by means of four 50-inch centrifugal pumps at other times.

The laterals are all drains of considerable size and follow the depressions or old sloughways. It was not intended that Reclamation District 2047 should provide complete lateral drainage but should

provide only sufficient outlets so that the several irrigation districts might complete the more detailed drainage as time and funds permitted. Although the drainage system in District 2047 affords flood protection to this region, as well as a means of unwatering rice lands, the work was stimulated by the drainage needs of the rice lands during the period of inflated prices. This district should therefore be considered as largely an obligation of the rice industry. It provided a means of securing a satisfactory drainage outlet for the various irrigation districts such as no one of the districts cared to provide without the cooperation of the others.

The construction of these works, which included not only the excavation for the main drain and laterals, but also the outlet pumping plant and numerous regulating structures, assumed an undertaking of considerable magnitude. The district has spent close to \$300,000 on construction and has issued 6 per cent bonds for nearly this amount. The assessments which were spread in proportion to the benefits received run from a maximum of about \$25 per acre to a nominal minimum, the average being about \$13 per acre. The picture on the cover of this bulletin is a view of the main drain in Reclamation District 2047 taken between Colusa and Maxwell.

With the exception of the Glenn-Colusa Irrigation District, there has been very little effective drainage done within the boundaries of Reclamation District 2047 other than that done by the reclamation district itself. The Glenn-Colusa District has outlined a very comprehensive drainage system upon which they began construction in 1922.

During the first three years of construction, something over 100 miles of drains were built at a cost of about \$160,000. It was planned to continue this work, spending \$60,000 per year until between 500 and 600 miles of drain had been completed; but as the work was planned primarily for rice lands, the decrease in acreage has not made it necessary to proceed so rapidly (see figure 7). The drains are comparatively shallow, averaging not more than 4 feet in depth. Due to the nature of these soils, however, this depth is probably as effective as greater depth would be. Drainage on these soils consists primarily of removing surface water at the time the fields are being unwatered. The drainage in this district is being paid for from current funds and no further bonded indebtedness has been incurred. At the present time practically all of the land producing rice regularly has been provided with drainage outlets.

It has been mentioned elsewhere that the heavier types of the Willows soils may in some instances contain considerable alkali which added to the fact that they are normally rather retentive of moisture adds somewhat to the difficulty of obtaining maximum results from the drains. The system of drainage which has been or will be provided in the Glenn-Colusa District should be ample for the needs of rice on a less refractory soil. A large portion of this area is not cropped, except to rice, and as a result has been idle for a number of years.



Fig. 7.—Some of the flatter and heavier soils in the Colusa Basin have not been planted since 1920. This view shows an old rice field which is now used for pasture. Pasturing, especially when the land is not irrigated, tends to keep cat-tail growth under control.

The better soils in this district, those which are free from alkali, and are slightly lighter in texture respond to drainage much better than the poorer types and are the soils now being used for rice and grain. These areas have also received their quota of the district's drains.

Some parts of the district are occupied by soils which are underlain with sandy and gravelly strata. These areas have much better natural drainage and are generally used for the production of alfalfa and fruits.

The Jacinto Irrigation District in which rice is no longer permitted has constructed a few shallow drains 2 to 4 feet deep, but they have had little effect on the ground water table. Rice is said to have caused considerable damage to orchards in this district and may yet be partially responsible for the high water table even though none is

grown in the district. The drainage which now exists in the Jacinto district is not sufficient for the orchards and alfalfa which are planted.

Two drains about 5 feet in depth constructed by the Glenn-Colusa Irrigation District and the main drain of District 2047 cross the Jacinto District.

The Princeton-Cadora-Glenn Irrigation District, in which there are several hundred acres of rice, has no drainage other than that provided by the Reclamation District.

The Provident Irrigation District is not extensively devoted to rice. A few shallow surface drains have been provided, but they are insufficient for the needs of the district.

The Maxwell Irrigation District was fortunate in receiving a number of drains from the work done by District 2047. At this time, however, nearly, if not fully one-half of the district is used as hunting grounds by organized duck clubs. These clubs have closed the drains and are pumping the water back onto the land. The remainder of the district is largely not farmed, although some of the higher, better drained areas are in rice and general farm crops. This district contains no drains other than those constructed by the Reclamation District.

The Compton-Delevan Irrigation District has no drainage other than that provided by the Reclamation District, but like the Maxwell District it received a considerable mileage of those drains. The Compton-Delevan District also contains land used by duck clubs and like both the Provident and Maxwell contains a large percentage of uncropped land.

It has been reported that approximately 165,000 acres in Reclamation District 2047 appears to be better suited to rice culture than to any other crop yet attempted. This, however, does not imply that profitable yields may be obtained from this entire area under the methods of rice growing now commonly employed. In 1924 the total area irrigated in the Reclamation District was slightly over 77,000 acres and less than one-half of this was in rice. It is generally conceded that following the common practice in rice growing that yields under 20 sacks per acre are unprofitable and much of the 165,000 acres referred to has not produced an average of 20 sacks per acre. Increased drainage facilities, improved cultural methods and fertilization may in the future materially alter these figures, but at the present time it is probably sound economics to permit this land to remain idle. In almost every case, especially on the Willows soils, those lands which produce satisfactory crops of rice will under favorable conditions produce good crops of wheat and barley.

The lighter-textured soils, those better suited to alfalfa, trees or other deep-rooted or more permanent crops, are difficult to keep properly submerged for rice, and the seepage and deep percolation losses are so great that the duty of water is excessively low. It has also been found that these soils seem to become foul with cat-tails more rapidly than do the heavier soils. There was a greater acreage of rice in Reclamation District 2047 during 1927 than in any year since 1920 and it was noticed that a considerable portion of this was grown on land that had not been planted for a number of years.

Other Sacramento Valley Areas.—In 1927 the Rice Growers Association of California reported about 4000 acres of rice in Yuba County and 5000 acres in Sacramento County. This was grown on scattered areas consisting mostly of soils of the San Joaquin series. These soils because of the layer of hardpan at about 30 inches, which would prevent excessive percolation losses, were considered particularly suited to rice and in 1920 were extensively planted in the Cordua Irrigation District northeast of Marysville and in the Arboga section southeast of Marysville. This assumption, however, was erroneous and the San Joaquin soils have not proven well suited to this crop. No organized effort has been made to drain these lands, they become badly waterlogged, and cat-tails and other aquatic weeds and grasses cause a great deal of trouble. They dry out slowly after unwatering, and as a result harvesting is often delayed. Unfortunately, there are not enough drains on these soils to make it possible to predict how they might respond to more extensive artificial drainage. On the whole, San Joaquin soils in their natural condition must be classed as rather unsatisfactory for rice and the extent to which these soils are planted will be governed largely by the condition of the rice market.

Merced County.—If one might judge from a limited experience with rice on the Madera and Fresno clays of Merced County, this region does not have adequate drainage for this crop. The 15,000 acres planted in this region in 1927 was a very substantial increase over any previous year and the Merced Irrigation District in which this land is situated was not able to provide drains rapidly enough to take care of this land. For various reasons, not all of which was poor drainage, but little over one-half of the planted acreage was harvested at the proper time and much of it not at all. The drainage which has been provided for this area consists of open drains following the natural depressions. Alkali is present to such an extent that the soils are badly puddled and water passes through them so slowly that they will undoubtedly be difficult to drain. These soils seem to dry out

very slowly making it difficult, if not impossible, to harvest the crop within a reasonable time after unwatering. The types of machinery commonly used for rice harvest could not traverse these muddy fields and a great deal of the 1927 crop in this area was lost. Conditions on the Panoche clay adobe soils of western Fresno County are somewhat better than those in Merced County.

All soils which contain much alkali, wherever they are located, are very difficult to get into proper condition for harvest after they are unwatered. This fact, together with a poor yield which usually occurs where alkali is present makes them less desirable. Any condition such as alkali, poor drainage, or unfavorable climatic conditions, which delays harvest even for so short a period as two to three weeks is quite objectionable in either the Sacramento or San Joaquin valleys. The development of new types of harvesting machinery which will be more successful in operating in wet fields may overcome some of these difficulties and make rapid drainage less necessary.

Imperial Valley.—The conditions under which rice is grown in Imperial Valley differ materially from those in the Sacramento and San Joaquin valleys. Rice growing has so recently been introduced into this valley that there has not yet been established what might be termed a common practice. Until recently (about 1924) the Imperial Irrigation District discouraged the growing of rice in the valley to the extent of refusing water for this crop. The reason for this refusal was that the district had not yet installed sufficient drainage to take care of waste water coming from rice fields and they believed that excessive seepage might endanger other crops in the vicinity. Rice is now grown in Imperial Valley (about 4,000 acres in 1927) in widely scattered localities and on various types of soil. For the most part, however, it is used as a reclamation crop on badly alkaline land.

An attempt is being made, with apparently considerable success, to grow rice on lands which have now been provided with deep drainage by the district, but which are too alkaline to produce alfalfa or grain sorghums. The long continued flooding necessary to produce a crop of rice has in many cases greatly reduced the alkali content of these soils and there is considerable evidence to indicate that after from one to three crops of rice the land will be in condition to grow such other crops as might be desired. Rice should not be attempted, however, on any lands in Imperial Valley which are not in close proximity to one of the district's deep drains.

At the present time it would appear best to consider rice in Imperial Valley only as a reclamation crop and not as one having very

great commercial possibilities. Climatic conditions are such that to produce a satisfactory milling rice, it is almost imperative that the crop be harvested just as soon as it is mature. The high alkali content of the soils which have so far been used and the large amount of silt which is deposited in the rice fields from the irrigation water both tend to delay drying of the soil and frequently several weeks are required before harvesting machinery can enter. This delay causes considerable loss from sun-checking, lodging, from birds and occasionally from rain. As has already been mentioned, the industry is so new in Imperial Valley and conditions are so different from other sections of the state that it is necessary to await further experience with the crop before reliable predictions can be made.

IRRIGATION REQUIREMENTS

The water requirements of rice in the Sacramento Valley have varied somewhat within the past few years due to improvements in drainage and cultural methods, but probably this variation is not greater than might be expected in a crop which has so recently become established. The average amount of water used, however, is considerably higher than for other crops. Although there are several factors influencing the amount of water used, such as variation in the available supply, preparation of land, length of growing season, the ability of the individual grower, etc., it appears that the type of soil on which the crop is grown has the greatest influence. Adams¹² in his work on rice irrigation in 1916 and 1917 showed a variation of from 3.91 acre-feet to 18.70 acre-feet as the gross duty of water on individual areas, and Dunshee¹³ in similar work in 1924 and 1925 shows a variation from 5.19 acre-feet to 8.34 acre-feet as the gross duty on different textured soils of the Willows series. Table 2, taken from Adams' report, is a summary of the duty of water measurements in the Sacramento Valley in 1916, 1917 and 1918, grouped by soil types.

Although these figures were obtained nearly ten years ago and methods of growing rice have changed somewhat Dunshee points out that there has been no material change in the duty of water requirements. The principal soils on which rice is now grown extensively and which can be termed as rice soils include only the first five of the following list.

¹² Adams, Frank, Rice irrigation measurements and experiments in Sacramento Valley. California Agr. Exp. Sta. Bul. 325:47-69, 1920.

¹³ Dunshee, Carroll F., Rice experiments in Sacramento Valley, 1922-1927. California Agr. Exp. Sta. Bul. 454:1-14, 1928.

Further inquiries as to the amount of water required for growing rice have brought forth the following information. In the West Yolo section on the Capay clay soil, the duty of water is probably higher than elsewhere. Here the average is said to be about 5 acre-feet. It is believed by some that a scarcity of water and the fact that there is no artificial drainage to take care of excesses is more largely responsible for the high duty than any peculiar characteristic of the Capay soils.

TABLE 2
DUTY OF WATER MEASUREMENTS ON SEVERAL OF THE RICE SOILS
OF THE SACRAMENTO VALLEY

Soil classification	Number of full season observations	Total area included in observations	Av. depth of water applied, in feet
Capay clay.....	2	355	3.94
Willows clay adobe.....	7	8,477	4.22
Willows clay.....	7	5,057	5.08
Stockton clay adobe.....	12	2,877	5.13
Sacramento clay.....	4	4,653	5.72
Tehama clay loam and clay.....	2	267	8.12
Vina clay loam.....	1	302	
Willows loam and clay.....	2	71	
Madera clay loam.....	1	172	
Willows loam.....	2	122	9.38
San Joaquin loam.....	3	51	10.94
Total or average.....	43	22,404	4.89

In Reclamation Districts 1500 and 108 where rice is grown on Sacramento clay, the duty of water is about 6 acre-feet. Both of these areas are farmed under close supervision by large operators and drainage has been amply provided.

On the Stockton clay adobe soils of Sutter and Butte counties from 6 to 6½ acre-feet of water are considered as the average amount used. On some of the pumped areas the duty of water is low (8 acre-feet or more) due to the fact that they usually are somewhat isolated and in a region of normally low water table and also the soil is frequently lighter in texture.

In Glenn and Colusa counties where the soils producing rice belong to the Willows series, it is estimated that nearly 7 acre-feet of water are required. Water is both cheap and plentiful in this section and the presence of alkali tends to increase the amount used. Rice grown on the light-textured soils invariably requires more water than neighboring heavy soils. The above figures, which are taken to

be gross duties, are not based on actual measurements, as were those in the Adams and Dunshee reports, but are estimates made by various persons whose judgment supplemented by some gross measurements are considered to be reliable. From a drainage standpoint gross duties are more significant than net duties since the excess invariably finds its way into the drainage channels and must be considered in the



Fig. 8.—Waste water surrounding a rice field may be unavoidable but it adds to the difficulty of weed control and ditch maintenance. View taken in Glenn-Colusa District in 1927. The soils are Willows clay loam.

design and especially the maintenance of drains. The growth of weeds in the drains, waterlogging of adjacent lands and similar problems may be to a considerable degree traceable to water which is in excess of the net amount required to produce a crop of rice. No data are available on the duty of water for rice in the San Joaquin or Imperial valleys. Figure 8 shows waste water and weed growth surrounding a rice field. This ditch has just been cleaned preparatory to unwatering the field.

SOCIAL CONDITIONS

The culture of rice introduces into the agriculture of the region a factor not found with other crops. The requirements and growing habits of rice in regard to the use of water and long submergence makes the territory in which it grows far less desirable from a residence standpoint than is the case with other crops. There is always, under the most favorable conditions, some seepage and waste water



Fig. 9.—A small family orchard of mixed fruits near Colusa which is entirely surrounded by rice fields and in which the water table is less than one foot from the surface during much of the year. This is one of the conditions which makes the rice lands undesirable as locations for homes.

from rice fields. Cat-tails and other water-loving plants usually surround the area and mosquitoes are prevalent. (See figure 9.) Not many people care to live on farms where rice is grown, but prefer rather to live in the towns or nearby cities. As a result social conditions in rural districts where rice is grown are uninviting. A large part of the rice is grown by tenants, some of whom are Orientals, and on short time leases. Most rice leases are on a crop share basis for one year and leases exceeding three years are rare. Rice farms are



Fig. 10.—Rice is grown either by tenants or owners of large tracts who establish temporary camps in the rice fields during harvest. This view taken east of Maxwell is typical of the rice camp and its surroundings.

operated from temporary headquarters called "camps" located in or near the rice fields which are occupied during only the busy season. Figure 10 shows a rice camp east of Maxwell.

Under the methods of rice culture now followed, it is not usually considered profitable to keep land in rice for more than three years in succession. Probably about three crops of rice in five years is the more common practice. For the first year following rice the land lies fallow, sometimes barley or wheat is raised the second year, then followed by rice again. Many rice farmers do not consider it profitable to grow grain, preferring to leave the land fallow whenever it is not in rice, although most of them will agree that land which has been in rice will produce larger yields of grain than if it had not been in rice. Very few tenant farmers grow grain.

In the vicinity of Richvale more rice land is farmed by resident owners than in any other section, many of these rotating rice and grain at more or less regular intervals. Probably grain is rotated with rice more extensively and regularly in the West Yolo area than elsewhere. New land or land which has not been in rice for a number of years is considered the most productive.

CONCLUSIONS

From the history and experience of the past decade in the drainage of rice lands in California, it may be concluded that drainage has three main functions. First, to put the land into such condition that it can be prepared for planting in the proper way by the most improved methods, and at the proper time; second, that the crop may be grown and matured with the least possible damage to other crops or land on nearby or adjacent fields; and third, that the rice fields may be unwatered and dried out so that the crop may be harvested with the least delay when it is mature.

In general, the drainage situation in most of the rice regions of California is fairly satisfactory for the rice crop. The heavy-textured soils required for rice are by nature among the more poorly drained and the most difficult to drain. Soils which are heavy enough to retard the downward movement of water sufficiently to permit long submergence without the use of excessive amounts dry out quickly when the surface water is removed.

For the most part, a high water table and rice culture go hand in hand. If the land becomes dry enough in the spring to be properly prepared for planting, and in the fall to permit the operation of

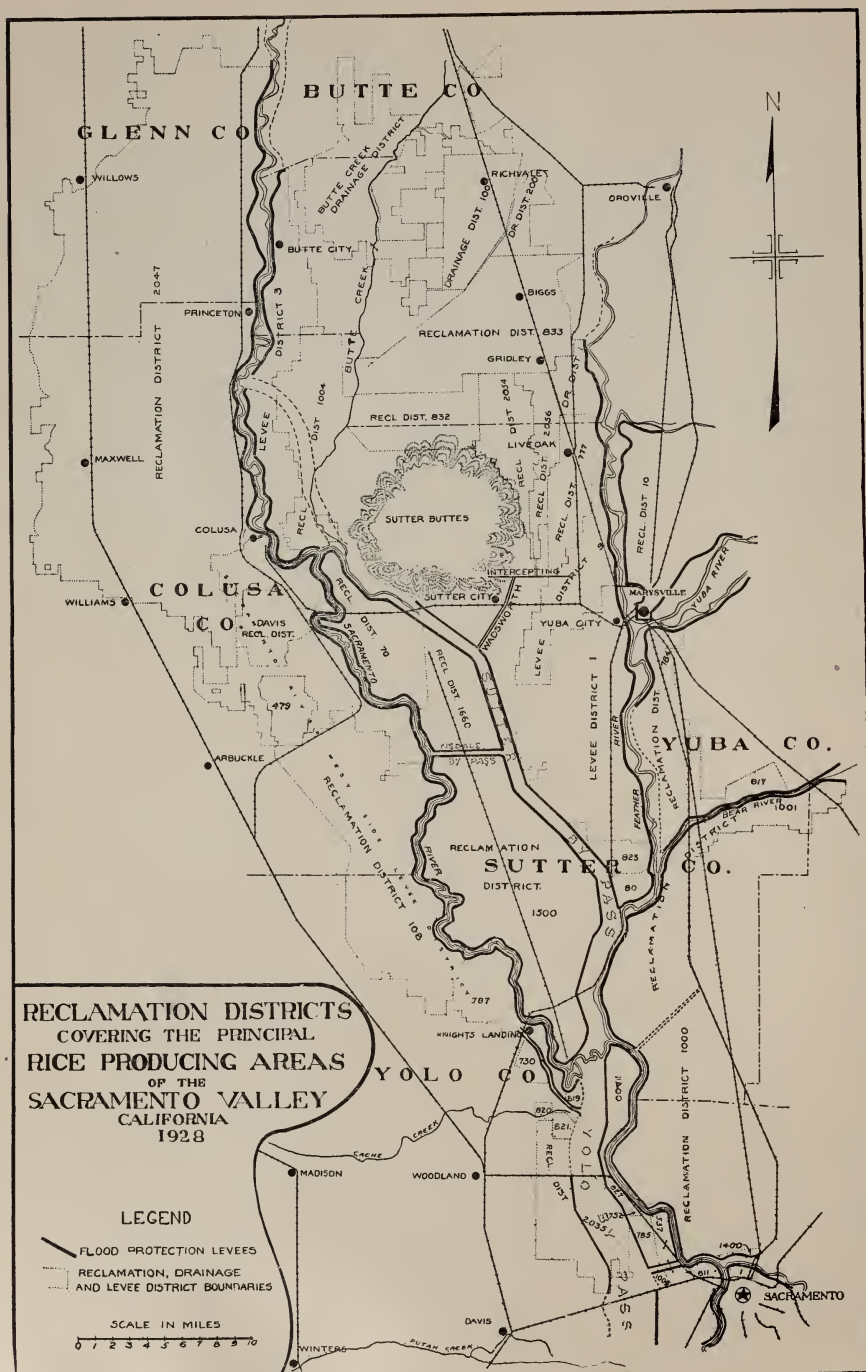


Fig. 11.—Map of a portion of the Sacramento Valley showing the Reclamation and Drainage Districts in which the principal rice growing areas are located.

harvesting machinery within about two weeks after unwatering, there does not appear to be any further correlation between the crop yield and the height of the water table.

Such drainage as will remove the winter's rainfall, which is usually not excessive in the regions where rice is grown, so as to permit the preparation of a good seed bed by the middle of April, should be considered sufficient. This amount of drainage can usually be obtained by keeping open and clear of weeds all of the natural drainage channels of the region and the connecting up with these channels of all roadside ditches and natural depressions. The amount of ditch work required will depend upon the surface slopes and the regularity of surface topography. For instance, more drainage would be required on the more irregular hardpan lands of the San Joaquin series than on the smoother lands of the Capay series.

In regions which are subject to overflow from streams or run-off from adjacent lands such as portions of the area along Butte Creek and Hamlin Slough in Butte County, Snake and Morrison rivers in Sutter County, and some of the "goose lands" in Glenn County, it is necessary to provide for this additional water. The drainage systems which now exist in all of these regions are ample for this purpose except possibly in unusual years or when the levees fail. This drainage is not intended to do more than remove the surface accumulations of water as rapidly as it is necessary in order that the land may be prepared for seeding.

After seeding and during the time the crop is growing, drainage is necessary to take care of seepage and waste from irrigation so that it does not accumulate along the roads and encroach upon other property. During this period of four to five months considerable injury might occur to nearby fields of other crops than rice. The amount of water to be taken care of at this time is not large and for the most part no other crops are grown among the rice fields. When rice is grown on more or less isolated areas among other crops proper drainage during the growing season is very important, and this drainage should be considered from the standpoint of protection to these crops rather than for the rice.

When rice is mature, it is desirable that it be harvested as soon as possible. After maturity rice may be injured or the yield materially reduced by lodging, sun-checking, and unseasonable rains. In the more remote and isolated rice fields considerable damage may be caused to mature unharvested rice by birds particularly blackbirds and ducks. These factors therefore require a short and early harvest

period. It is necessary, therefore, under the harvesting practices now common in California, that the fields be unwatered as the crop approaches maturity. Unwatering is usually started before full maturity and where the drainage is adequate and the soil not too refractory from ten days to two weeks is sufficient time to allow before actual cutting begins.

The rice harvest season normally lasts from four to six weeks. This means, therefore, that from 5 to 8 inches in depth of water from the entire rice acreage must be discharged into and be carried away by the drainage system during this period. Fortunately, the streams and natural channels which must eventually receive this water are at their lowest stage and there is always a good outlet. If there is an open drain in good repair alongside of or at the lowest point of every rice field there will be no difficulty in disposing of the water at the unwatering period. The type and arrangement of the drainage now existing over much of the rice area appear to be satisfactory for the required drainage at this time. Drainage Districts 100 and 200 and Reclamation Districts 833, 2054 and 2056 and most of the Glenn-Colusa Irrigation District all have drains which are satisfactory.

As has already been mentioned, however, the lack of drains in the West Yolo area does not appear to have been a serious handicap, whereas in some portions of Reclamation District 2047 and in Merced County the absence of adequate drainage has been a detriment.

Where rice is the only crop under consideration, the amount of drainage necessary for the different soil conditions has apparently been fairly well worked out by experience. There is unquestionably a very important economic factor to be considered in planning drainage for rice lands and it might easily happen that more money can be spent on this type of improvement than will be justified by the increased yield. This point may have already been reached in some sections.

Where crops other than rice may be used as part of a rotation system with rice or where protection to permanent crops on adjacent lands is to be considered, better drainage will be required than for rice alone. Just how far the districts may wisely proceed in this matter is problematical. It might be better to entirely prohibit the growing of rice in these sections than to attempt to install drainage which will give the necessary protection to other crops. Because rice on such lands usually requires much more than the normal amount of water and often many times the amount used for other

crops, some plan of water tolls, in which unusual amounts become excessively expensive, will tend to restrict the growing of rice on lands suited to other crops. Local public sentiment also may have considerable influence for or against the planting of rice in certain sections.

The principal areas devoted to rice are occupied by soils which on account of texture, topography or some other reason are not usually well suited to other crops and rotation with grain or field crops has not proven highly satisfactory even in those areas such as Drainage District 100 which enjoys better than average drainage. It is doubtful if economic conditions are now such as to justify intensive drainage systems, if indeed such would accomplish the results, which will permit the growing of other crops than rice in the typically rice areas or make these areas desirable from a residence standpoint.

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